Evolutionary Techniques of GAMS used in Optimization of economic load dispatch in Power system

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Abstract

In the electric power supply systems, there exist a wide range of problems involving optimization processes. Among them, the power system scheduling is one of the most important problems in the operation and management ANY power system optimization problems including economic dispatch (ED) have noconvex characteristics with heavy equality and inequality constraints . The objective of ED is to determine an optimal combination of power output to meet the demand at minimum cost while satisfying the constraints. For simplicity, the cost function for each unit in the ED problems has been approximately represented by a single quadratic function and is solved using mathematical programming techniques .Economic load dispatch has the objective of generation allocation to the power generators such that the total fuel cost is minimized and all operating constraints are satisfied. Generally ELD is solved without accounting for transmission constraints, however, in deregulated power system environment Economic load dispatch (ELD) has the objective of generation allocation to the power generators such that the total fuel cost is minimized and all operating constraints are satisfied. Generally ELD is solved without accounting for transmission constraints, however, in deregulated power system environment. A number of traditional methods are used for solving ELD and other power system problems. During the last decade soft computing methods like particle swarm optimization (PSO),GA and lemda iteration method have been increasingly proposed for complex optimization problems. The paper reviews and compares the performance of the proposed PSO,GA and iteration method variants with traditional solver GAMS for economic dispatch on TWO standard test systems having different sizes and complexity levels. A large 38-unit power system is included for validating the results.

Keywords: **Optimization of Economic load dispatch ,GAMS, Electric power generation; Thermal generator constraints;**

1 Introduction

Most of power system optimization problems including economic dispatch (ED) have complex and nonlinear characteristics with heavy equality and inequality constraints [1]. Economic dispatch is one of the most important problems to be solved in the operation and planning of a power system Power utilities try to achieve high operating efficiency to produce cheap electricity. GA [7] Competition exists in the electricity supply industry in generation and in the marketing of electricity. The operating cost of a power pool can be reduced if the areas with more economic units generate larger power than their load, and export the surplus power to other areas than their load, and export the surplus power to other areas with more expensive units. On the other hand, ELD is one of the most crucial issues of present energy management system. The objective of ELD in a power system is to discover the best possible combination of power output for all generating units which will minimize the total fuel cost as well as satisfying load and operational constraints. The ELD problem is extremely complex to work out because of its large dimension, a non-linear objective function, and various constraints. several analysis on the ELD have been carried out till now, suitable improvements in the unit outputs scheduling can contribute to significant cost savings [3]The benefits thus gained will depend on several factors like the characteristics of a pool, the policies adopted by utilities, types of interconnections, tie-line limits and load distribution in different areas. Therefore, transmission capacity constraints in production cost analysis are important issues in the operation and planning of electric power systems. Soft computing based approaches are also becoming very popular. Although these methods do not always guarantee global best solutions, they often achieve a fast and near global optimal solution. Recently covariance matrix adapted evolutionary strategy has been proposed problems. Large dimension problems are difficult to optimize using soft computing methods, as these techniques take a long time to converge; on the other hand, traditional methods like the GAMS solver computes the best result almost instantaneously. Many researchers have been done for the problem as reported in the literature [8] [9]. At the early time, the objective function of the ED problem was approximately represented by a single quadratic function so that mathematical programming techniques could be implemented to solve it This paper proposes some modified PSO GA local minima and enhance global search. [10]There has been phenomenal growth in mathematical programming techniques and development of computer codes to solve large scale optimization models over the past four to five decades. There has also been noteworthy development in relational database for improved data organization and transformation capabilities.. A number of efficient modelling languages have been developed which makes use of both the development in improved database management and mathematical programming techniques. One of the most popular and flexible languages among these is the General Algebraic Modelling System (GAMS) [2]. GAMS module was originally developed through a World Bank funded study in 1988.

2 The General Algebraic Modelling System (GAMS) solvers

The General Algebraic Modelling System (GAMS) is specifically designed for modelling linear, nonlinear and mixed integer optimization problems. [2] The system is particularly very advantageous with large, complex problems. GAMS allows the user to concentrate on the modelling problem by making the setup simple. GAMS is especially useful for handling large, complex, one-of-a-kind problems which may require many revisions to establish an accurate model.. The user can change the formulation quickly and easily, and can even change from one solver to another. Similarly the use can easily convert from linear to nonlinear optimization option with little trouble.[2] GAMS main window show in the fig 1 and fig 2 show .

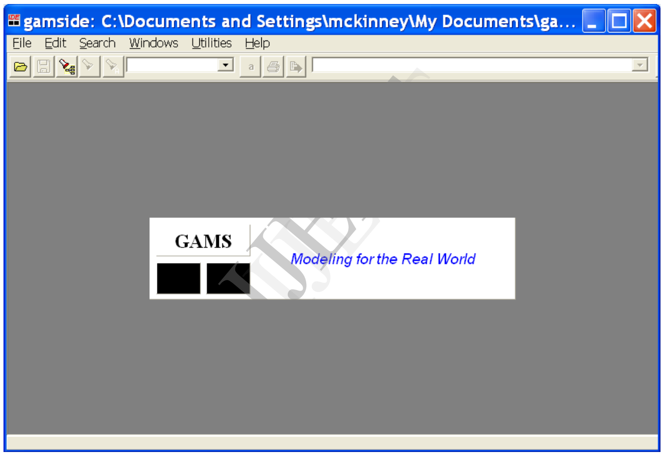


Fig. 1 GAMS main window

the optimization solver ,in GAMS modelling system solve the different problems of linear, nonlinear and mixed integer optimization problems.

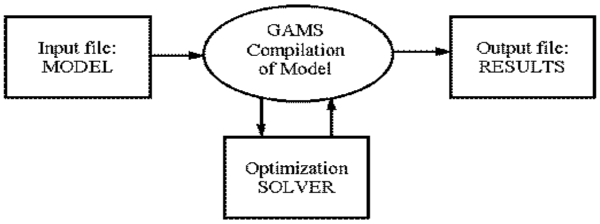


Fig 2. Optimization solver

Using the tools show in the table 1 and table 2,recently use of GAMS are using the different area show in the table 3 and worldwide use this tools show the fig.3 The basic structure of a mathematical model coded in GAMS has the components: sets, data, variable, equation, model and output The tool kit in GAMS gives algorithms for each category of problem. GAMS also has the unique feature of providing a common language that can make use of a variety of solvers

Fig 3 Academic + Commercial Users Worldwide OF GAMS

Table 1: Structure of GAMS model [2]

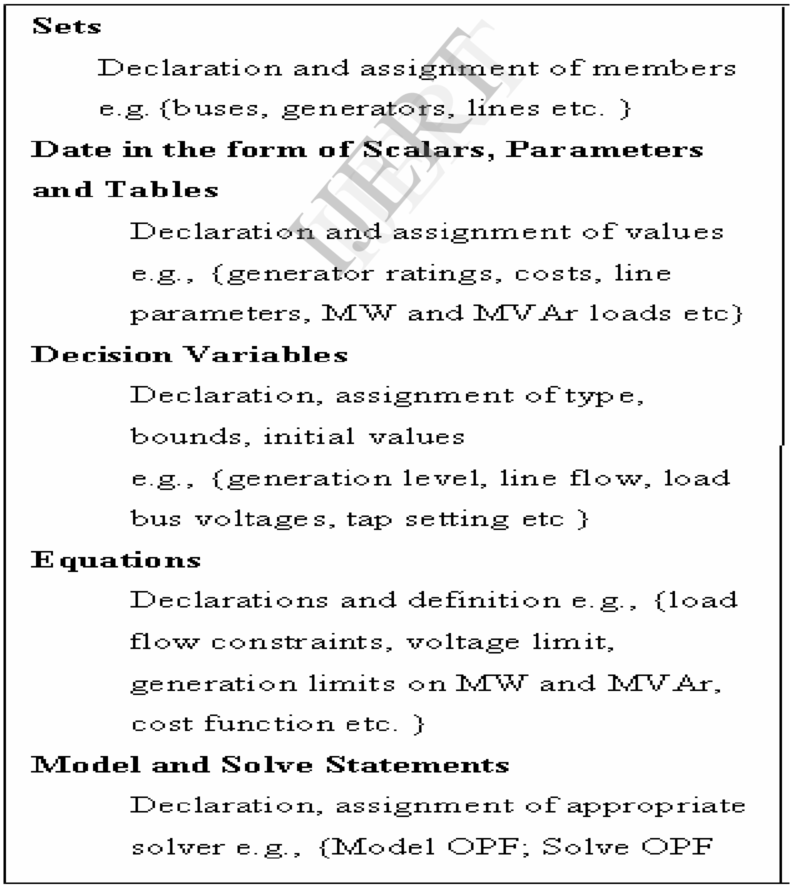
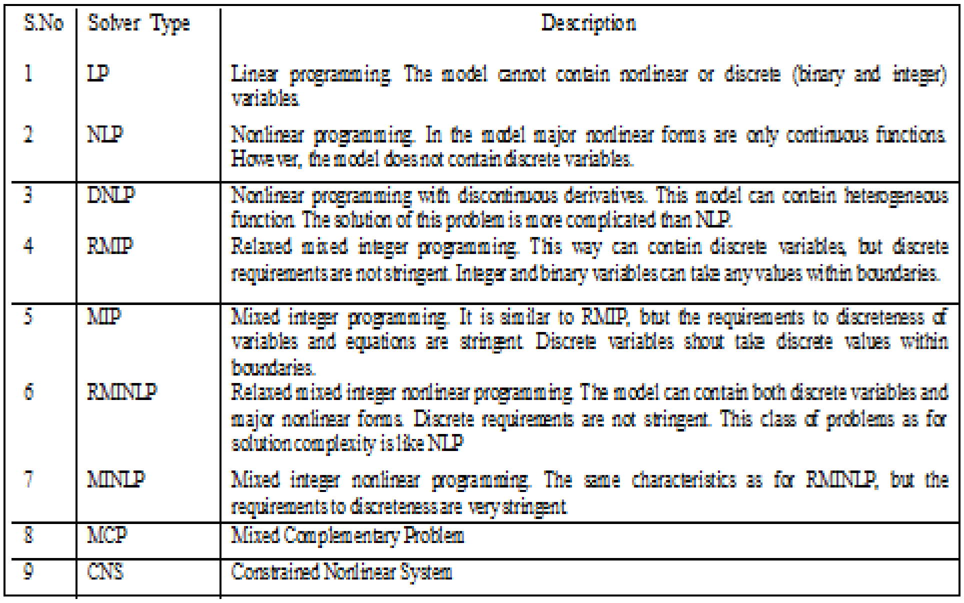
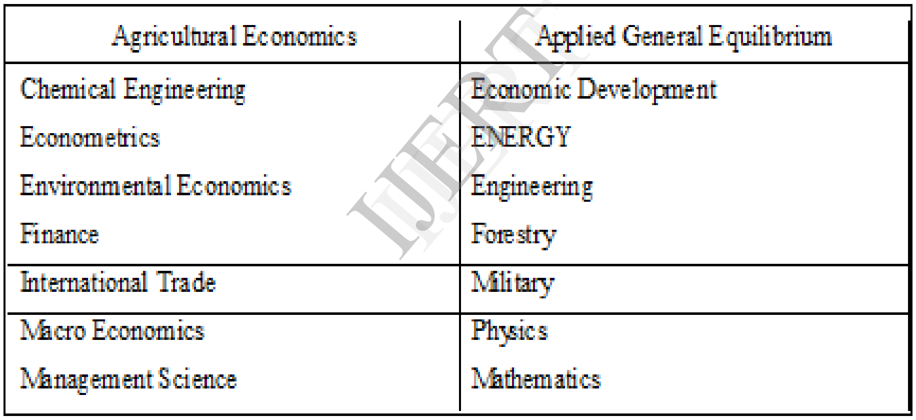

Sets
Declaration and assignment of members
e.g. {buses, generators, lines etc. }
Date in the form of Scalars, Parameters and Tables
Declaration and assignment of values
e.g., {generator ratings, costs, line parameters, MW and MVAr loads etc}
Decision Variables
Declaration, assignment of type, bounds, initial values
e.g., {generation level, line flow, load bus voltages, tap setting etc }
Equations
Declarations and definition e.g., {load flow constraints, voltage limit, generation limits on MW and MVAr, cost function etc. }
Model and Solve Statements
Declaration, assignment of appropriate solver e.g., {Model OPF; Solve OPF

Table 2 Methods of Solving Optimization Problems.[3,4]



S.No	Solver Type	Description
1	LP	Linear programming. The model cannot contain nonlinear or discrete (binary and integer) variables.
2	NLP	Nonlinear programming. In the model major nonlinear forms are only continuous functions. However, the model does not contain discrete variables.
3	DNLP	Nonlinear programming with discontinuous derivatives. This model can contain heterogeneous function. The solution of this problem is more complicated than NLP.
4	RMIP	Relaxed mixed integer programming. This way can contain discrete variables, but discrete requirements are not stringent. Integer and binary variables can take any values within boundaries.
5	MIP	Mixed integer programming. It is similar to RMIP, but the requirements to discreteness of variables and equations are stringent. Discrete variables shout take discrete values within boundaries.
6	RMINLP	Relaxed mixed integer nonlinear programming. The model can contain both discrete variables and major nonlinear forms. Discrete requirements are not stringent. This class of problems as for solution complexity is like NLP
7	MINLP	Mixed integer nonlinear programming. The same characteristics as for RMINLP, but the requirements to discreteness are very stringent
8	MCP	Mixed Complementary Problem
9	CNS	Constrained Nonlinear System

Table 3 GAMS Are Using The Different Area[4]



Agricultural Economics	Applied General Equilibrium
Chemical Engineering	Economic Development
Econometrics	ENERGY
Environmental Economics	Engineering
Finance	Forestry
International Trade	Military
Macro Economics	Physics
Management Science	Mathematics

3. Economic load dispatch Formulation

The objective of an ELD problem is to find the optimal combination of power generations that minimizes the total generation cost while satisfying an equality constraint and inequality constraints. The fuel cost curve for any unit is assumed to be approximated by segments of quadratic functions of the active power output of the generator. For a given power system network, the problem may be described as optimization (minimization) of total fuel cost as defined by (1) under a set of operating constraints

$$F_T = \sum_{i=1}^{n} F(P_i) = \sum_{i=1}^{n} \left(a_i P_i^2 + b_i P_i + c_i \right) \tag{1}$$

where is F_T total fuel cost of generation in the system ($/hr), a_i, b_i, and c_i are the cost coefficient of the i th generator, P_i is the power generated by the i th unit and n is the number of generators. The cost is minimized subjected to the following generator capacities and active power balance constraints.

$$P_{i,\min} \le P_i \le P_{i,\max} \quad \text{for } i = 1, 2, \cdots, n \tag{2}$$

where Pi, min and Pi, max are the minimum and maximum power output of the i th unit.

$$P_D = \sum_{i=1}^{n} P_i - P_{Loss} \quad (3)$$

where P_D is the total power demand and P_{Loss} is total transmission loss. The transmission loss PLoss can be calculated by using B matrix technique and is defined by (4)

$$P_{Loss} = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \quad (4)$$

where B_{ij} „s are the elements of loss coefficient matrix **B**

4 Results and Discussions

The performance of traditional optimization approach using the NLP minimization module of GAMS has been compared with DE,BBO, Iteration method and PSO, for two test cases having different sizes and complexity levels as described below. Simulations were carried out using MATLAB 7.0.1 on a Pentium IV processor, 2.8 GHz. with 1 GB RAM.

4.1 Description of the test cases

The performance of traditional optimization approach using the NLP minimization module of GAMS has been compared GA, Iteration method and PSO and its variants for two test cases .

1) Test case I: This system is taken from [5] . It has 4-generating units supplying a total load of 520 MW. Transmission losses are neglected while minimizing cost function given by eq. (1) subject to constraints given by (2) .The fuel-cost characteristics are given in Table 4.[5]

2) Test case 2: This system is taken from [6] . It has 38-generating units supplying a total load of 8550 MW. Transmission losses are neglected while minimizing cost function.

Test Case -1

This system comprises of 4 generating units and the input data of 4-generator system are given in cost coefficients of generating unit Table 4.[5] Here, the total demand for the system is set to 530 MW. and different load demand 200 to 1200 MW The obtained results for the 4-generator system using the GAMS are given in Table 6 and the results are compared with those from pso classical ,pso accelerated and gradient method . in finding a global optimal solution presented In The Table [5].

Table 4 cost coefficients of generating unit [5]

Unit	c_i ($/MW2)	b_i($/MW)	a_i ($)	P_i^{min} (MW)	P_i^{max}(MW)
1	750	18.24	0.00875	30	120
2	680	18.87	0.00754	50	160
3	650	19.05	0.00310	50	200
4	900	17.90	0.00423	100	300

4.2 Comparison of Results for 4 unit system

The minimum cost reported for the 4 unit system with pso classical and pso accelerated or gradient method are 12919.96$ or 12919.76 [5].The best cost $ 12919.75 has obtained by the GAMS and Result has compared with PSO ,gradient method show in table 5 .

Table 5 Comparison of Results for 4 unit system

Variable	PSO Classical	PSO Accelerated	Gradient method	**GAMS**
P1 (MW)	88.554	92.536	92.493	**92.494**
P2 (MW)	65.340	65.539	65.559	**65.560**
P3 (MW)	134.662	130.293	130.431	**130.427**
P4 (MW)	231.444	231.632	231.517	**231.519**
Total power [MW]	520.00	520.00	520.00	**520.00**
Total fuel cost($/h)	12919.96	12919.76	12919.76	**12919.754**
Time (sec)	<1	<1	<1	**0.16**

4.3 Effect of load variation for 4 unit system

Load was changed from the test case (I) 200 MW to 1200 MW) and it was found that the system did not convergence for 800 MW. It can be seen from Table 6. And show in the fig 4.with increase in load the optimal cost was found to increase.

Table 6 : Results of optimal dispatch with changing

S No.	LOAD(MW)	COST($/h)	Violation	CPU time(s)
1	200(MW)	7289.975	-0.000	0.15
2	300(MW)	8616.594	0.000	0.16
3	400(MW)	10554.753	0.000	0.16
4	500(MW)	12523.088	0.000	0.15
5	600(MW)	14516.398	-0.000	0.16
6	700(MW)	16534.556	0.000	0.16
7	800(MW)	18191.724	-0.000	0.15
8	900(MW)	18191.724	0.000	0.15
9	1000(MW)	18191.724	0.000	0.16
10	1200(MW)	18191.724	0.000	0.16

4.4 Effect of Generator Outage contingency

In practical power system operation power generators often become faulty and are not available. In this paper each generator is considered out of service one by one for load demands of 200, 300, 400, 500, 6000, 700 , 800, 900 ,1000 and 1100 MW for test case I. Comparison of best results of one by one generator outage can be seen from Table 7 and graphical representation is shown Figure 5. Results of optimal dispatch with generator outage contingency for load demand 400 has been shown in Table 8.so that outage of Gen1 maximum cost of **$10544.753** was computed. Least operational cost (**$10785.296**) was found for outage of Gen.4.

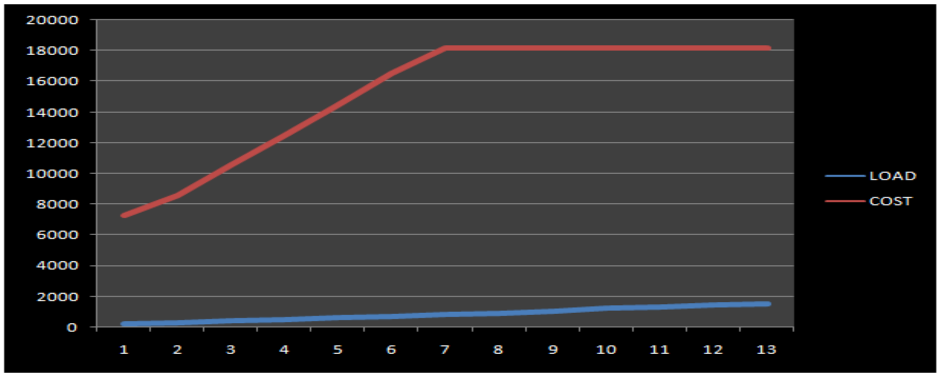


Fig 4: Generator for different load demands (Test case I)

Table 7 : Comparison of best results of one by one generator out for different loads (test case I)

S.N0	LOAD(MW)	P1(COST)	P2(COST)	P3(COST)	P4(COST)
1	200	6734.900	6703.802	6705.902	6805.727
2	300	8649.964	8618.697	8621.043	8777.827
3	400	10612.679	10573.537	10589.687	10785.296
4	500	12605.048	12558.083	12600.556	12441.024
5	600	14627.024	14572.334	14257.724	12441.024
6	700	15876.924	14979.500	14257.724	12441.024
7	800	15876.924	14979.500	14257.724	12441.024
8	900	15876.924	14979.500	14257.724	12441.024
9	1000	15876.924	14979.500	14257.724	12441.024
10	1100	15876.924	14979.500	14257.724	12441.024

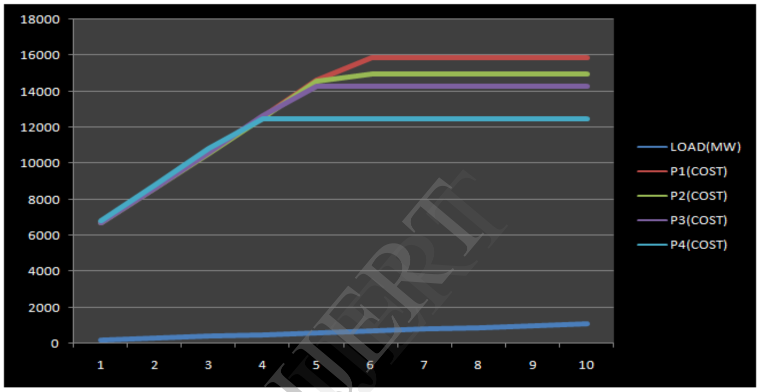


Fig 5: Generator outage cases for different load demands (Test case I)

Table 8 :Results of optimal dispatch with generator outage contingency (test case I: PD=400 MW)

S.No	All units	P1 out	P2 out	P3 out	P4 out
P1	74.766	0000	83.253	94.960	114.874
P2	50.000	60.286	0000	68.421	91.531
P3	80.388	117.59	104.344	0000	193.595
P4	194.847	222.117	212.403	236.619	0000
Total Cost($/h)	10554.753	10612.679	10573.537	10589.687	10785.296

Test case 2

The coefficient of fuel cost and maximum and minimum power limits are given in table 10 [6].The power demand is to be 8550 (MW).The results corresponding to DE/BBO,BBO,PSO,NEWPSO and GAMS are detailed in section table 9 .the comparison of results of all methods shown in table 9.

Table 10: Fuel cost coefficient of Test case I

Unit	a_i (\$MW^2)	bi (\$MW)	c_i (\$)	P_i^{min} (MW)	P_i^{max} (MW)
1	64782	796.9	0.3133	220	550
2	64782	796.9	0.3133	220	550
3	64670	795.5	0.3127	200	500
4	64670	795.5	0.3127	200	500
5	64670	795.5	0.3127	200	500
6	64670	795.5	0.3127	200	500
7	64670	795.5	0.3127	200	500
8	64670	795.5	0.3127	200	500
9	172832	915.7	0.7075	114	500
10	172832	915.7	0.7075	114	500
11	176003	884.2	0.7515	114	500
12	173028	884.2	0.7083	114	500
13	91340	1250.1	0.4211	110	500
14	63440	1298.6	0.5145	90	365
15	65468	1298.6	0.5691	82	365
16	77282	1290.8	0.5691	120	325
17	190928	238.1	2.5881	65	315
18	285372	1149.5	3.8734	65	315
19	271676	1269.1	3.6842	65	315
20	39197	696.1	0.4921	120	272
21	45576	660.2	0.5728	120	272
22	28770	803.2	0.3572	110	260
23	36902	818.2	0.9415	80	190
24	105510	33.5	52.123	10	150
25	22233	805.4	1.1421	60	125
26	30953	707.1	2.0275	55	110
27	17044	833.6	3.0744	35	75
28	81079	288.7	16.765	20	70
29	124767	1024.4	26.355	20	70
30	121915	837.1	30.575	20	70
31	120780	1305.2	25.098	20	70
32	104441	716.6	33.722	20	60
33	83224	1633.9	23.915	25	60
34	111281	969.6	32.562	18	60
35	64142	2625.8	18.362	8	60
36	103519	1633.9	23.915	25	60
37	13547	694.7	8.482	20	38
38	13518	655.9	9.693	20	38

Table 9 comparison of best result load (8550MW)

Output(MW)	DE/BBO	BBO	PSO-TVAC	NEW-PSO	EP-EPSO	GAMS
P1	426.606060	422.230586	443.659	550.000	318.0777	**418.390**
P2	426.606054	422.117933	342.956	512.263	475.117	**418.390**
P3	429.663164	435.779411	433.117	485.733	399.1265	**421.431**
P4	429.663181	445.481950	500.000	391.083	500.0000	**500.000**
P5	429.663193	428.475752	410.539	443.846	500.0000	**421.431**
P6	429.663164	428.649254	492.864	358.398	500.0000	**421.431**
P7	429.663185	428.119288	409.483	415.729	500.0000	**421.431**
P8	429.663168	429.900663	446.079	320.816	500.0000	**421.431**
P9	114.000000	115.904947	119.566	115.347	114.0000	**114.000**
P10	114.000000	114.115368	137.274	204.422	132.7826	**114.000**
P11	119.768000	115.418662	138.933	114.000	114.0000	**116.343**
P12	127.072800	127.511404	155.401	249.197	144.0000	**123.438**
P13	110.000000	110.000948	121.719	118.886	110.0000	**110.000**
P14	90.000000	90.0217671	90.924	102.802	90.0000	**90.000**
P15	82.000000	82.0000000	97.941	89.039	82.0000	**92.000**
P16	120.000000	120.038496	128.106	120.000	120.0000	**120.000**
P17	159.598000	160.303835	189.108	156.562	141.9435	**158.603**
P18	65.000000	65.0001141	65.000	84.265	65.0000	**65.000**
P19	65.000000	65.0001370	65.000	65.041	65.0000	**65.000**
P20	272.000000	271.999591	267.422	151.104	120.0000	**272.000**
P21	272.000000	271.872268	221.383	226.344	272.0000	**272.000**
P22	260.000000	259.732054	130.804	209.298	260.0000	**260.000**
P23	130.648618	125.993076	124.269	85.719	80.0000	**127.914**
P24	10.000000	10.4134771	11.535	10.000	10.0000	**10.000**
P25	113.305034	109.417723	77.103	60.000	92.9577	**111.051**
P26	88.0669159	89.3772664	55.018	90.489	55.0000	**86.797**
P27	37.5051018	36.4110655	75.000	39.670	35.0000	**36.668**
P28	20.0000000	20.0098880	21.682	20.000	20.0000	**22.975**
P29	20.0000000	20.0089554	29.829	20.985	20.0000	**20.000**
P30	20.0000000	20.0000000	20.326	22.810	20.0000	**20.000**
P31	20.0000000	20.0000000	20.000	20.000	20.0000	**20.000**
P32	20.0000000	20.0033959	21.840	20.416	20.0000	**20.000**
P33	25.0000000	25.0066586	25.620	25.000	25.0000	**25.000**
P34	18.0000000	18.0222107	24.261	21.319	18.0000	**18.000**
P35	8.0000000	8.00004260	9.667	9.122	8.0000	**8.000**
P36	25.0000000	25.0060660	25.000	25.184	25.0000	**25.000**
P37	21.7820000	22.0005641	31.642	20.000	38.0000	**21.479**
P38	21.0621792	20.6076309	29.935	25.104	20.0000	**20.797**
Cost(\$/h)	9,417,235.78	9,417,633.63	9,500,448,.30	9,596,448.31	9,387,925.49	9,220,800.00

5 Conclusion

This paper presents an efficient and simple approach for solving the economic load dispatch (ELD) problem The performance of PSO variants was compared with traditional NLP solver GAMS for economic dispatch problem of four test cases. Soft computing techniques like the PSO use random operators for achieving the optimal result therefore in every fresh trial, these methods converge to different solutions near the global best solution. The traditional NLP algorithm like the GAMS uses mathematical operations to achieve the best solution so they are always consistent and converge to the unique global minimum solution. The time taken by soft computing techniques is quite large as compared to GAMS. The time requirement increases tremendously with problem complexity (like the inclusion of losses) and with increase in problem size. No such issue is there with GAMS.

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